MSC-23314-1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Christiansen et al. § Examiner: Jordan M. Lofdahl

Serial No.: 09/892,355 § Group Art Unit: 3644

Filed: June 26, 2001 §

Title: Flexible Multi-Shock Shield §

15/Decl
9/12/13
Holmes

Commissioner for Patents
U.S. Patent and Trademark Office
P.O. Box 2327
Arlington, VA 22202

CERTIFICATE OF MAILING UNDER 37 C.F.R. §1.8(a)
I hereby certify that this correspondence is being deposited with the U.S. Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, U.S. Patent and Trademark Office, P.O. Box 2327, Arlington, VA 22202, on July 29, 2003.
By: James M Cate
Signature: James M Cate

Dear Sir:

DECLARATION UNDER 37 C.F.R. § 1.132

I, Lalit C. Chhabildas, hereby declare:

1. I am at least 18 years of age and am competent in all respects to make the following statements.

2. I live at 3716 Tewa Dr. N.E., Albuquerque, NM, 87111

3. I have a Bachelors Degree in Physics from The University of Bombay, INDIA; and a Doctorate in Physics from Rensselaer Polytechnic Institute, United States. I am a member of the American Physical Society (APS), Hypervelocity Impact Society (HVIS), Aeroballistics Range Association (ARA), and have been the President of the Hyper Velocity Impact Society, Chairman of the APS - Topical Group on Shock Compression of Condensed Matter, and am the Chairman of the Awards Committee of the APS -Topical Group on Shock Compression of Condensed Matter. For over 26 years, I have specialized in the field of hypervelocity impact. I have authored or co-authored over 350 technical articles in this field. My Curriculum Vitae is attached as Appendix A.

4. I consider myself to be a person of at least ordinary skill in the art of hypervelocity impact.

5. I am not now, nor have I ever been, in the employment of the assignee of the present application.

6. I have reviewed U.S. Patent No. 6,298,765 (Dvorak), entitled "Multi-shock Assembly for Protecting a Spacecraft Surface From Hypervelocity Impactors." Although the multi-shock shielding concept described in the patent is interesting, it is not readily apparent how a person of ordinary skill in my field would practically apply this shielding concept to spacecraft protection without a large investment in time, energy, and resource to assess how much shielding is required. For example, it is not readily apparent from the patent how a desired level of protection would be achieved for a particular shield design in terms of the particle mass, velocity, and angle that would just reach, but not exceed the failure threshold of the shield. In essence, the Dvorak patent does not contain sufficient information to teach a person of ordinary skill in my field how to effectively put the multi-shock shielding concept into practice.

6. I have also reviewed the present application, with special attention to the mathematical relationships embodied in Equations 1-5 contained therein. In my opinion, these relationships are essential in order to teach a person of ordinary skill in my field how to successfully design the multi-shock shields described in the application to defend against particular threat particles (those of a given size, velocity, impact angle and density). Equations 1-5 are therefore necessary in real world applications of the multi-shock shielding concept to spacecraft protection from meteoroid and orbital debris particles with high confidence of success. The equations mathematically explain the physical process and the relevant parameters associated with the design and performance of the multi-shock shield. This is crucial in providing an efficient and predictive

process when changing materials in the design of advanced shielding concepts without an excess amount of experimentation.

7. Further, Equations 1-5 are not generally known to, nor can they be easily derived by, a person with my education, training, and experience. I hold this opinion because of my own efforts in developing similar equations on numerous projects such as developing constitutive relations for use in hydrodynamic codes for design and predictive tools for advanced concepts in armor and shielding. Based on my experience, equations such as Equations 1-5 cannot be developed by a person having ordinary skill in my field without having a considerable amount of data from actual tests and theoretical studies. The data must then be compiled and statistically analyzed, and mathematical models representing the data must be developed and verified. Only after extensive verification are the mathematical models set forth as equations. Such a process, based on my experience in the field of hypervelocity impact, is enormously expensive and time consuming.

8. I declare further that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such false statements may jeopardize the validity of the application or any patent issuing thereon. Executed on January 15th, 2003.

Lalit C. Chhabildas

Lalit C. Chhabildas

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	§	Examiner: Jordan M. Lofdahl
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July 29, 2003
By: James M Cate
Signature: James M Cate

Dear Sir:

DECLARATION UNDER 37 C.F.R. § 1.132

I, Charles E. Anderson, Jr., hereby declare:

1. I am at least 18 years of age and am competent in all respects to make the following statements.

2. I work at Southwest Research Institute, 6220 Culebra Road, San Antonio, TX, 78238

3. I have a Bachelors Degree in Physics from Virginia Polytechnic Institute & State University, and a Masters degree and a Ph. D. in Physics from Rensselaer Polytechnic Institute, United States. I am a member of the American Physical Society (APS), Hypervelocity Impact Society (HVIS), the International Ballistics Committee (IBC), Sigma Xi, and the American Association for the Advancement of Science (AAAS). I am active in the APS, and in particular, the Topical Group on Shock Compression in Condensed Matter, participating technically with scientific papers and organizationally as Session Chair at most of the topical conferences over the last 15 or so years. I was a founding Board member and the first president of the Hypervelocity Impact Society, and am

currently an elected member of the Board of Directors, having just been re-elected by the membership for a new 6-year term. I have over 30 years of experience in high-rate loading research, and have specialized in penetration mechanics, including hypervelocity impact, since approximately 1982. I have authored or co-authored over 170 technical articles, and over 90 technical reports. Further, because of my knowledge and expertise in penetration mechanics, I have been a member of several different "expert" or "Blue Ribbon" panels that have been formed by various U.S. Government organizations to review, assess and provide recommendations in the general area of high-rate loading and penetration/armor mechanics, including—but not limited to—hypervelocity impact. My Curriculum Vitae is attached as Appendix A.

4. I consider myself to be a person of at least ordinary skill, and probably an expert, in the art of hypervelocity impact.

5. I am not now, nor have I ever been, in the employment of the assignee of the present application.

6. I have reviewed U.S. Patent No. 6,298,765 (Dvorak), entitled "Multi-shock Assembly for Protecting a Spacecraft Surface From Hypervelocity Impactors." Although the multi-shock shielding concept described in the patent has technical merit, the description is of only a general nature; and it is not readily apparent how a person of ordinary skill in my field would apply this shielding concept to spacecraft protection. The Multi-shock Assembly is comprised of a variety of modern, flexible materials such as Kevlar™, Spectra™, Nextel™ (fabric and foam), open-cell and/or closed-cell foams, etc. It is not apparent from the patent how these materials should be assembled to achieve a desired level of protection from the impact of a hypervelocity impactor that is characterized by its density, diameter, mass, velocity, and impact angle. The Dvorak patent does not contain sufficient information to teach a person of ordinary skill in my field how to put the multi-shock

shielding concept into practice without a large investment in time, energy, and resource to assess how much shielding is required to achieve a reliable level of protection.

6. I have also reviewed the present application, with special attention to the mathematical relationships embodied in Equations 1-5. These equations mathematically explain the physical process and the relevant parameters associated with the design and performance of the multi-shock shield (in terms of the areal density of the flexible shield layers and the areal density of the back wall, and spacing between the flexible shield and the back wall) to defend against particular threat impactors (described by their density, diameter, mass, velocity, and impact angle). In my opinion, these relationships are essential in order to teach a person of ordinary skill in my field how to successfully design the multi-shock shields described in the application.

7. Further, Equations 1-5 cannot be easily derived by a person with my education, training, and experience without considerable experimentation and analysis. I hold this opinion because of my own knowledge of efforts by investigators to develop shielding equations for hypervelocity impact from meteoroids and orbital debris. In particular, I have been the Guest Editor for seven (7) volumes—and I am currently editing an eighth volume—of the *Proceedings of the Hypervelocity Impact Symposia*, published in the peer reviewed ***International Journal of Impact Engineering***. Based on my experience and knowledge of the field, equations such as Equations 1-5 cannot be developed by a person having ordinary skill in my field without having assembled a considerable amount of experimental data from actual tests, perhaps supplemented by theoretical studies. These data must then be compiled and statistically analyzed, and mathematical models representing the data must be developed and verified. Only after extensive verification are the mathematical models set forth as engineering equations useful for design applications. Such a process, based on my experience in the field of hypervelocity impact, is enormously difficult and time

consuming.

8. In my opinion, Equations 1-5 are crucial in providing an efficient and predictive process when changing materials in the design of advanced shielding concepts without an excess amount of experimentation. Equations 1-5 are therefore necessary in real world applications of the multi-shock shielding concept to spacecraft protection from hypervelocity impact.

9. I declare further that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such false statements may jeopardize the validity of the application or any patent issuing thereon. Executed on 18 July, 2003.

Charles E. Anderson, Jr.

CHARLES E. ANDERSON, JR.
Director, Engineering Dynamics Department
Mechanical and Materials Engineering Division

B.S. in Physics, Virginia Polytechnic Institute, 1968
M.S. in Physics, Rensselaer Polytechnic Institute, 1972
Ph.D. in Physics, Rensselaer Polytechnic Institute, 1972

Dr. Anderson has worked extensively on modifying and improving the predictive capabilities of the large Eulerian and Lagrangian hydrocodes, and has used them for fundamental and applied analyses of warhead fragmentation effects, warhead concept development for ballistic missile defense, penetration mechanics, hypervelocity impact, and armor/anti-armor impact interactions. Dr. Anderson organized and is a lecturer for *A Short Course on Penetration Mechanics*, taught by the Institute. The course presents and develops the fundamental and underlying principles of penetration mechanics including experimental, analytical, and numerical approaches to penetration and perforation physics. He is coauthor of the course notes. Other active areas of research at SwRI have included the development of thermodynamic heat transfer model for intumescent (expanding) thermal protective systems, predictive modeling and analysis of highly transient thermal pulses from HE detonations within enclosures and rocket motor cookoff. More recently, Dr. Anderson has been involved in the development and assessment of advanced, lightweight armor concepts; and weapons effects on next-generation Navy ships (specifically, missile magazines and composite deck house).

In 1986, Dr. Anderson received a Technical Leadership Award for leading the development of an advanced capability in shock physics including the analytical and computational modeling of complex problems in high rate deformation mechanics. A second Technical Leadership Award was presented in 1995 for a vigorous high quality program in engineering dynamics and ballistics. Because of his acknowledged expertise in penetration and computational mechanics, Dr. Anderson has served on various Government advisory committees. In the fall of 1988, Dr. Anderson was the chairman of a Blue Ribbon Panel for DARPA to evaluate and make recommendations concerning the KE Impact Physics Program, with specific attention to hypervelocity impact. In 1989, he served on the DARPA/ONR/ARO Advisory Group on Constitutive Modeling for Large-Scale Numerical Computations of Nonlinear Behavior, and a DOD/DOE Advisory Group on Computational Computer Programs for Modeling Dynamic Material Response. In 1993-1994, Dr. Anderson participated in the Future Technologies Workshop conducted by ARL/TARDEC. Dr. Anderson and his co-authors won the Best Paper Award at the *1992 Hypervelocity Impact Symposium*, and the Best Poster Award at the *17th International Symposium on Ballistics* (1998). In 2000, Dr. Anderson received the *HVIS Distinguished Scientist Award*, given for significant and lasting contributions to the science of hypervelocity ballistics. In 2002, Dr. Anderson was appointed to the National Academies' *ARL Technical Assessment Board's Panel on Armor & Armaments.*

Dr. Anderson has authored numerous Government reports and has presented papers at national and international technical conferences and published extensively in the disciplines of computer simulations, the mechanics of high-rate loading response, and penetration mechanics including hypervelocity impact. A number of these articles are co-authored with internationally-known investigators from other research organizations. He was the Technical Program Chairman for the *1986 Hypervelocity Impact Symposium* (*HVIS*), *1989 HVIS* and the *1992 HVIS*; and is the editor of the proceedings for the *1986, 1989, 1992, 1994, 1996, 1998, and 2000* symposia which have been published as special volumes of *International Journal of Impact Engineering.* He is also the co-chairman of the *1999 International Ballistics Symposium.* Dr. Anderson is listed in *American Men and Women in Science*, *Who's Who in the American Southwest, Who's Who in Science and Engineering, International Who's Who of Professionals, and Who's Who in the World.* Dr. Anderson is a member of the Editorial Advisory Board for the *International Journal of Impact Engineering,* a member of the *International Ballistics Committee*, and is a *Senior Institute Fellow* of the Institute for Advanced Technology of The University of Texas at Austin.

PROFESSIONAL CHRONOLOGY: Active Duty as U.S. Army Reserve Officer (1972-1974); Research Physicist, U.S. Army Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland (1974-80); Southwest Research Institute (Senior Research Physicist, Department of Energetic Systems, 1980-1984; Manager, Dynamic Analysis Section, 1984-1988; Manager, Ballistic Sciences Section, 1988-1993; Director, Engineering Dynamics Department, 1994-).

MEMBERSHIPS: Sigma Xi; Association for the Advancement of Science; American Physical Society (Topical Group on Shock Waves in Condensed Matter), Hypervelocity Impact Society (Board of Directors, 1988-1994, 1996-present; President, 1989-1992; Past-President 1992-1994; Publications Chairman 1992-present).

LIST OF PAPERS AND PRESENTATIONS

by

Charles E. Anderson, Jr.

1. "Quasi-Static Pressure, Duration, and Impulse for Explosions in Structures," by W. E. Baker, C. E. Anderson, Jr., B. L. Morris, and D. K. Wauters, 20th DoD Explosives Safety Seminar, Norfolk, VA, August 1982.

2. "Rail Tank Car Safety by Fire Protection," by C. E. Anderson, Jr., *6th Int. Fire Protection Seminar,* Karlsruhe, Germany, September 1982.

3. "A Parametric Analysis of the Penetration Process," by J. L. Rand, C. E. Anderson, Jr., and J. S. Wilbeck, *7th Int. Symp. on Ballistics,* The Hague, The Netherlands, April 1983.

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5. "Thermodynamic Heat Transfer Model for Intumescent Coatings," by C. E. Anderson, Jr., D. K. Wauters, and D. F. Pulley, CPIA Publication 381, Vol. 1, Chemical Propulsion Information Agency, Laurel, MD, pp. 231-240, 1983.

6. "The Response of Intumescent Paints to Heat," by J. Buckmaster, C. Anderson, and A. Nachman, *Proc. Int. Colloquium on Free Boundary Problems*, Maubuisson, France, Pitman Publishing, Ltd., June 1984.

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9. "Intumescent Reaction Mechanisms," by C. E. Anderson, Jr., J. Dziuk, W. A. Mallow, and J. Buckmaster, *J. Fire Sci.,* **3** (3), pp. 160-194, 1985.

10. "A Heuristic Predictive Model for the Failure of Composite Pressure Vessel Subjected to Laser Irradiation," by M. F. Kanninen, J. W. Cardinal, and C. E. Anderson, Jr., *AIAA Laser Effects and Target Response Meeting,* Menlo Park, November 5-7, 1985.

11. "Computational Modeling of Explosive-Filled Cylinders," by C. E. Anderson, Jr., W. W. Predebon, and R. R. Karpp, *Int. J. Engng. Sci.,* **23** (12), pp. 1317-1330, 1985.

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14. "Spread of Fire Effects Between Rooms: A Computational Model," by C. E. Anderson, Jr., D. K. O'Kelley, and A. F. Grand, *J. Fire Sci.,* **4** (6), pp. 365-396, 1986.

15. "The Sandia Computerized Shock Compression Bibliographical Database," by J. Wilbeck, C. Anderson, J. Hokanson, J. Asay, D. Grady, B. Graham, and M. Kipp, **Metallurgical Application of Shock-Wave and High-Strain-Rate Phenomena**, edited by Murr/Straudhammer and Meyers, Marcel Dekker, NY, pp. 357-367, 1986.

16. "A Fracture Mechanics Analysis for the Failure of Filament-Wound Pressurized Cylinders Subjected to Intense Energy Disposition," by C. E. Anderson, Jr., J. W. Cardinal, M. F. Kanninen, presented at the *Army Symp. Solid Mech. 1986*, West Point, NY, October, 1986.

17. "An Overview of the Theory of Hydrocodes," by C. E. Anderson, Jr., *Int. J. Impact Engng.*, **5** (1-4), pp. 33-59, 1987.

18. "History and Application of Hydrocodes in Hypervelocity Impact," by W. E. Johnson and C. E. Anderson, Jr., *Int. J. Impact Engng.*, **5** (1-4), pp. 423-439, 1987.

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20. "Finite Element Analysis of Localized Mechanical Failure of Rocket Motors in the Cookoff Environment," by S. A. Mullin, P. A. Cox and C. E. Anderson, Jr., CPIA Publication 464, Vol. II, Chemical Propulsion Information System, Laurel, MD, 1987.

21. "Flyer Plate Impact of Dry Soils: An Instrumentation Calibration Technique," by C. E. Anderson, Jr., P. E. O'Donoghue, J. D. Renick and D. K. O'Kelley, *DNA Conference on Instrumentation for Nuclear Weapons Effects Testing*, October 6-8, Arlington, VA, 1987.

22. "Shock Propagation and Its Influence on Spall in Explosive Launching of Preformed Fragments," by P. E. O'Donoghue, C. E. Anderson, Jr., and W. W. Predebon, **Impact Loading and Dynamic Behavior of Materials**, Vol. II, edited by Chen, Kunze and Meyer, DGM Informationsgesellschaft, Oberursel, pp. 1041-1050, 1988.

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28. "Calibration of Stress and Motion Instrumentation for Dry Soils," by J. D. Renick, C. E. Anderson, Jr., P. O'Donoghue, D. K. O'Kelley and C. Felice, *J. Appl. Phys.*, **63** (5), pp. 1428-1437, 1988.

29. "Ballistic Impact: The Status of Analytical and Numerical Modeling," by C. E. Anderson, Jr. and S. R. Bodner, *Int. J. Impact Engng.*, **7** (1), pp. 9-35, 1988.

30. "A Mixture Theory Approach to the Modeling of Fiber-Reinforced Composites Subject to Impulsive Loading," by P. E. O'Donoghue and C. E. Anderson, Jr., **Computational Mechanics - Theory and Applications**, edited by S. N. Atluri and G. Yagawa, Springer-Verlag, NY, pp. 20.iii. 1-4, 1988.

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36. "Shock Propagation and Damage in Explosively Launched Cubical Fragments," by C. E. Anderson, Jr., P. E. O'Donoghue, and S. R. Bodner, *Int. J. Impact Engng.*, **8** (1), pp. 69-81, 1989.

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40. "Comparison of a High Velocity Impact Model with Numerical Simulation," by P. E. O'Donoghue, S. R. Bodner, C. E. Anderson, Jr., and M. Ravid, *Int. J. Impact Engng.*, **8** (4), pp. 289-301, 1989.

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42. "Anisotropic Model Development for Shock Applications," by C. E. Anderson, Jr., P. E. O'Donoghue and D. Skerhut, **Shock Compression in Condensed Matter 1989**, edited by S. C. Schmidt, J. N. Johnson, and L. W. Davison, Elsevier Science Publishers B.V., Amsterdam, pp. 177-180, 1990.

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49. "Impact Calculations of $L/D \leq 1$ Penetrators," by D. L. Orphal, C. E. Anderson, Jr., and R. R. Franzen, *Proc. 12^{th} Int. Ballistics Symp.*, **1**, pp. 458-464, San Antonio, TX, Oct. 30 - Nov. 1, 1990.

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51. "Numerical Simulations of SHPB Experiments of Ceramics," by C. E. Anderson, Jr., P. E. O'Donoghue, J. Lankford, and J. Walker, *Proc. 1991 Combat Vehicle Survivability Symp.*, Vol. II, pp. 167-175, April 15-17, Gathersburg, MD, 1991.

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53. "Dynamic Compressive Failure of Ceramics Under Confinement," by J. Lankford, C. E. Anderson, Jr., G. R. Johnson, and T. J. Holmquist, *Proc. 1991 Combat Vehicle Survivability Conf.*, Vol. II, pp. 67-73, April 15-17, Gaithersburg, MD, 1991.

54. "An Examination of Long-Rod Penetration," by C. E. Anderson, Jr. and J. D. Walker, *Int. J. Impact Engng.*, Vol. 11, No. 4, pp. 481-501, 1991.

55. "The Application of Dissimilar Material Velocity Scaling to Hypervelocity Impacts on Spacecraft," by S. A. Mullin, D. L. Littlefield, C. E. Anderson, Jr., and N. T. Tsai, *Proc. 62^{nd} Shock and Vibration Symp.*, Vol. IV, pp. 756-764, Springfield, VA, October 29-31, 1991.

56. "Numerical Examination of Long-Rod Penetration," by C. E. Anderson, Jr., *22^{nd} Midwestern Mechanics Conference*, University of Missouri-Rolla, October 1991.

57. "The Role of Microstructure in Deformation and Failure of Tungsten Heavy Alloys," by J. Lankford, A. Bose, H. Couque, and C. E. Anderson, Jr., **Proc. 12^{th} Army Symp. on Solid Mechanics**, S. S. Chou (Editor), pp. 117-138, Plymouth, MA, Nov. 1991.

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